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Investigation of wind energy potential of Muradiye in Manisa, Turkey

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ABSTRACT

The purpose of this survey is about to investigate wind energy potential of Celal Bayar University Muradiye Campus. The experimental system was commissioned in November 2006 and performance monitoring tests have been conducted since then. Author also undertake a case study to investigate how varying wind speeds considered affect the electricity production of the wind turbine system and to estimate a capacity factor which is defined as the ratio of the average power output to the rated output power of the generator. The collected data are quantified and illustrated in the tables, 07th of November 2006 till 09st of December 2007 for comparison purposes. According to experimental studies between 2006 and 2007 years, yearly average wind velocity is found to be 3.21 m/s at 30 m height and capacity factor is estimated to be 14.1% for Enercon E48 (800 kW) wind turbine. According to these results, the mean wind speed does not provide economical electricity production from the wind energy.

Contents

1. Introduction

There is a growing global demand for wind energy production. A lot of studies related to the wind characteristics and wind power potential have been made in many countries in the last decade [1]. For Turkey, electricity consumption is rising about 9% a year and this is increasing each year. Turkey imports around 70% of its cumulative energy needs. External dependence of energy increases the importance of renewable energy [2–4]. In Turkey, electricity generation through wind energy for general use was first realized in 1986 with a 55 kW nominal wind energy capacity in Izmir. Utilization of wind energy in Turkey has increased since 1998 when the first wind power plant (1.5 MW) was installed in Çeşme-Izmir. By the end of 2008 seventeen wind power plants were installed with a total capacity of 433.35 MW [5]. By the end of 2009 it is expected to be around 850 MW by the new ones. In Turkey, only 0.3% of electricity production is provided by wind turbines [6,7].

The effects of temperature, humidity, density etc. should always be taken into account when planning wind farms. There is abundant literature and reports on the effect of these parameters on power performance and these effects are well described in the IEC 61400-12-1 [8]. Therefore, a detailed knowledge of these parameters at particular location provides effective utilization and correct investments of wind energy systems.

The distribution of wind speeds is important for the design of wind farms, power generators and agricultural applications such as the irrigation. Today, wind analysis provides remarkable information to researchers and designers that are involved in renewable energy studies [9]. Knowledge of the wind speed frequency distribution is a very important factor to evaluate the wind potential in windy areas. If ever the wind speed distribution in any windy site is known, the power potential and the economic feasibility belonging to the site can be easily obtained [10,11].

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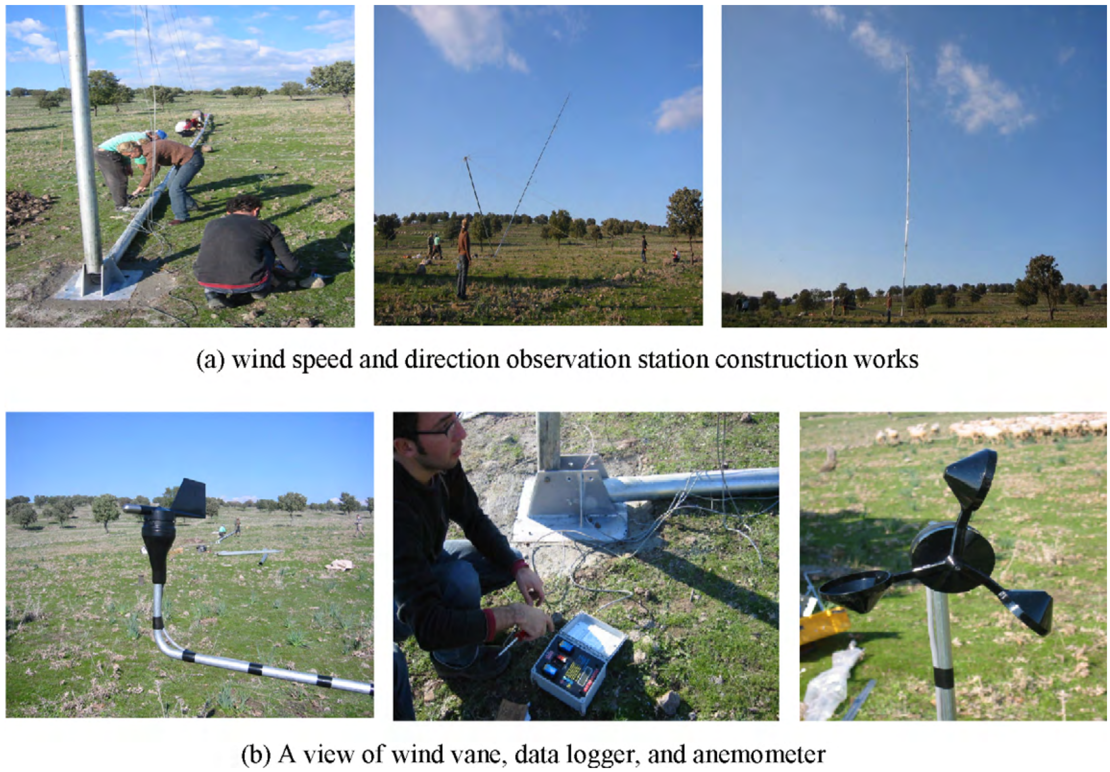

Fig. 1. Various views of the appearances of the constructed system: (a) wind speed and direction observation station construction works and (b) a view of wind vane, data logger, and anemometer.

In this study, author also undertake a case study to investigate how varying wind speeds considered affect the electricity production of the wind turbine system and to estimate a capacity factor [12] which is defined as the ratio of the average power output to the rated output power of the generator. The collected data are quantified and illustrated in the tables, 07th of November 2006 till 09st of December 2007 for comparison purposes. According to experimental studies between 2006 and 2007 years, yearly average wind velocity is found to be 3.21 m/s at 30 m height and capacity factor is estimated to be 14.1% for Enercon E48 (800 kW) wind turbine. According to these results, the mean wind speed does not provide economical electricity production from the wind energy.

2. Experimental facilities and total uncertainties

While determining the position of the wind observation station installed at Celal Bayar University Muradiye Campus, the buildings and other factors that hinder measurement were taken in to consideration to ensure that there were no obstacles at the wind ward side of the station. It means that there were no obstacles around the measurement area. The experimental system was commissioned in November 2006. The wind data measurement was a 30 m tall tubular tower. The constructed experimental system is illustrated in Fig. 1. This system mainly consists of three main separate circuits: (i) it has 3 cup anemometers, which were at 10, 20, and 30 m heights and one wind vane at 30 m height, (ii) temperature was obtained from a thermometer, and (iii) a data logger was connected with all sensors on the mast to collect data in a time series, and finally a computer was used to transfer the data from the data logger to be evaluated. The main characteristics of the elements of the system are given in Table 1. The data collection was made at an interval of every second and the hourly average values are also recorded. As known, errors and uncertainties in data recording and experiments may arise from instrument selection, instrument condition, instrument calibration, environment, observation, and reading and test planning. An uncertainty analysis was needed to prove the accuracy and reliability of the experimental data taken. As a result; the total uncertainties of the measurements are given Table 1. Data logger has a resolution of 0.1 °C, 0.1% m/s for temperature and wind velocity and its accuracy of 0.1 m/s.

3. Results and discussion

The project entitled Investigation of Wind Energy Potential of Muradiye Campus Area, in Manisa, Turkey in the Celal Bayar University Project No: 2006/37 was launched November 2006. This project aims to explore wind energy potential of Muradiye, Manisa. In the present study, the results obtained from the experiments were evaluated to determine the overall wind energy potential of Muradiye, Manisa.

Table 1
The main characteristics of the elements of the system.

Specification	Anemometer	Thermometer	Wind vane
Measurement range	1–96 m/s	(−40) °C to (52.5) °C	0–360°
Accuracy	Within 0.1 m/s (0.2 mph) for the range 5–25 m/s	±0.8 °C	±0.02%
Operating temperature range	(−5) °C to (+60) °C	(−40) °C to (52.5) °C	(−55) °C to (+60) °C
Resolution	0.1%	0.1%	0.1%
Trademark	NRG#40	NRG#110S	NRG#200P

Table 2
Measured wind speed report between November 2006 and December 2007.

	Channel number				
	1	2	3	4	5
Heights	10 m	20 m	30 m		
Units	m/s	m/s	m/s	°	°
Intervals with valid data	58085	58085	58085	58085	58085
Minimum interval average	0.4	0.4	0.4		
Date of minimum interval	07/11/06	07/11/06	07/11/06		
Time of minimum Interval	23:20	23:10	23:10		
Maximum interval average	19	16.9	15.3		
Date of maximum interval	23/03/07	23/03/07	23/03/07		
Time of maximum interval	03:50	03:50	03:50		
Date of minimum sample	08/12/06	08/12/06	08/12/06		
Time of minimum sample	22:00	22:00	22:00		
Minimum sample	0.4	0.4	0.44		
Maximum sample					
Date of maximum sample					
Time of maximum sample	09:30	09:30	09:30		
Maximum sample	27.5	26.34	24.84		
Wind speed direction				Northeast	North

(1–3) anemometer; (4 and 5) wind direction.

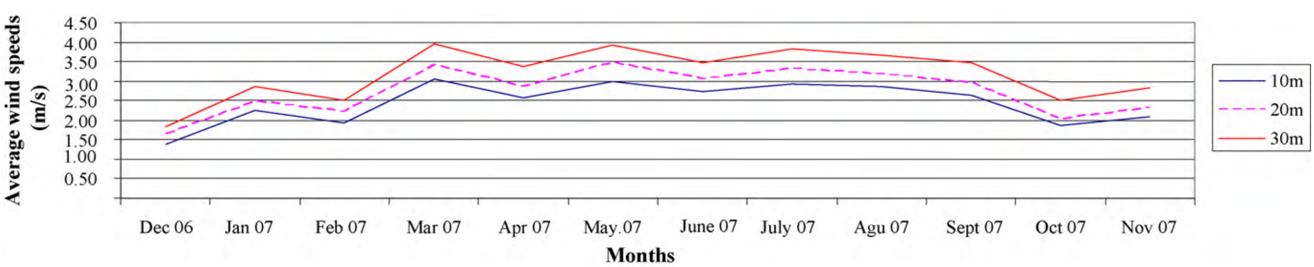

Fig. 2. Distribution of long term monthly average wind speeds at 10 m, 20 m, and 30 m height.

At least 1 year long measurement of data from observation station is required in order to determine the wind energy potential and project feasibility. Of course, it is preferable to have wind speed data for 5 years, if the case is available [10]. During this investigation, information on the speed and direction of the wind was collected for 14 months, making use of anemometers placed at the 10th, 20th, and 30th meters of the measurement mast.

3.1. Experimental observations

The monthly average ambient air temperatures varied between 5.9 and 31.7 °C during the experimental studies. Ambient temperature measurement is very important due to defining the normalized air density. According to experimental results, normalized air density was assumed to be 1.196 kg/m^3 the monthly distribution of wind speed measured November 2006 and December 2007 is illustrated in Table 2 and Fig. 2. for the 10, 20, and 30 m heights. According to these results, the average speed for 10 m was 2.45 and it was 2.76 m/s and 3.21 m/s for 20 and 30 m. The wind energy density is a function of the distribution of wind speeds and the effect of air density [10]. The mean value of energy density was measured as 19.78 W/m^2. When the variation of wind speed measured for 12 months between November 2006 and December 2007 was examined taking account of the seasons, it is found that the wind speed was high in spring months, reduced in the autumn and reached its minimum level (2.52 m/s) in October 2007. The wind

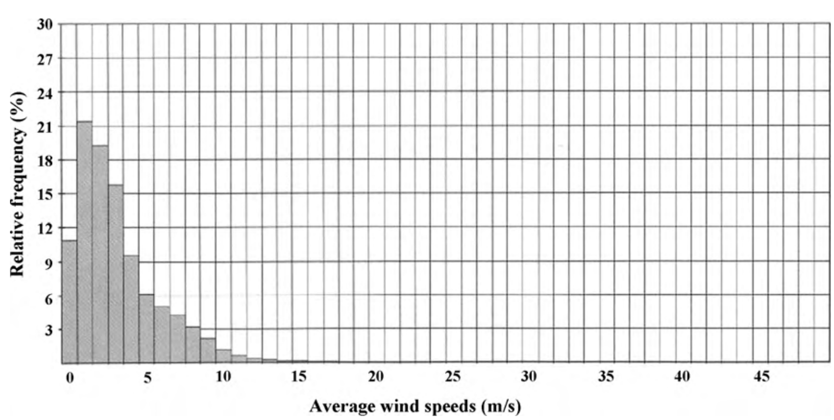

Fig. 3. Measured frequency histogram between 2006 November and December 2007.

Table 3
Measured wind speeds and wind directions distributions for November 2006-December 2007.

Wind speed (m/s)	Sector number and wind directions degrees																Total hours
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	0	23	45	68	90	113	135	158	180	203	225	248	270	293	315	338	
0	26	29	28	37	26	25	28	16	22	9	17	16	12	15	18	12	336
1	79	96	155	149	128	75	74	55	51	63	54	55	65	49	72	58	1278
2	72	91	142	190	204	124	79	59	54	41	44	40	44	36	40	60	1320
3	55	96	174	245	224	158	69	35	32	43	32	34	42	49	60	42	1390
4	43	66	181	175	185	79	25	25	15	14	25	18	34	79	58	29	1051
5	45	68	194	148	102	24	8	9	15	14	21	25	44	95	57	24	893
6	59	48	70	67	51	9	4	5	14	10	25	36	41	81	44	29	593
7	55	31	43	27	32	8	3	3	9	9	14	37	55	56	38	27	447
8	76	35	23	18	19	2	5	3	7	13	19	33	45	22	40	21	381
9	62	29	24	32	4	1	3	1	4	11	15	36	29	12	34	22	319
10	44	31	19	24	3	1	1	7	8	16	11	48	21	8	20	6	268
11	33	15	18	7	1	2	3	2	5	17	9	51	12	2	11	1	189
12	9	9	22	3	2	0	2	3	2	9	4	33	14	0	3	0	115
13	5	3	11	3	4	2	3	5	5	4	4	12	9	0	1	0	71
14	1	6	7	1	4	0	0	1	4	6	2	5	3	0	0	0	40
15	2	2	6	0	2	0	0	1	2	0	0	2	3	0	0	0	20
16	0	3	2	2	0	0	0	0	0	2	1	5	2	0	0	0	17
17	0	1	0	0	0	1	0	0	3	2	0	4	1	0	1	0	13
18	0	0	0	1	1	0	0	0	0	0	2	2	0	0	0	0	6
19	0	0	0	0	1	0	0	0	0	2	0	1	2	0	0	0	6
20	0	0	0	0	1	0	0	3	1	1	0	0	0	0	0	0	6
21	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	666	659	1119	1129	994	511	307	233	253	286	299	493	479	504	497	331	8760

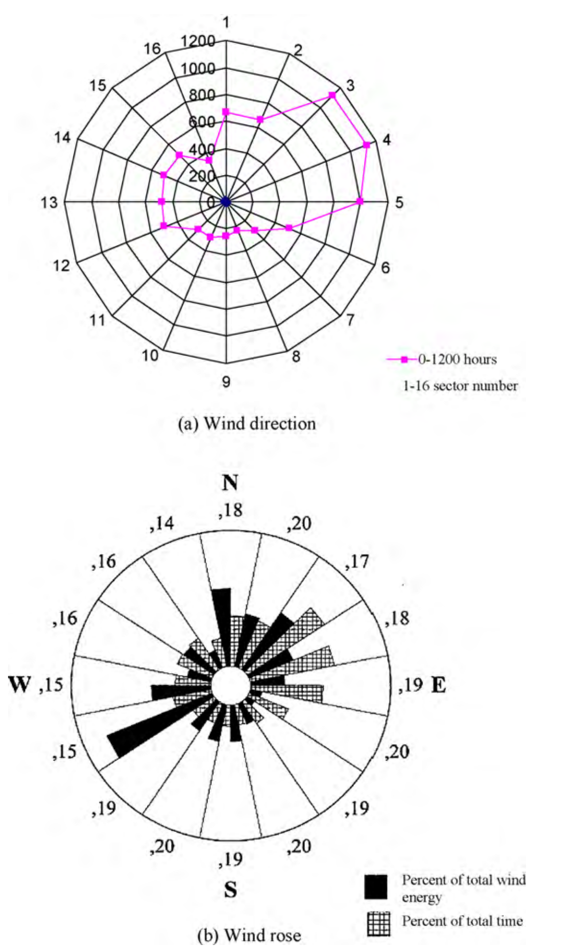

Fig. 4. Annual wind directions and wind rose: (a) wind directions and (b) wind rose.

speed started rising again after this month and reached the value of 3.96 m/s in March 2007. The wind energy density was 37.14 W/m^2 in March 2007 and its minimum level (9.57 W/m^2) was in October 2007.

Fig. 3 reflects the wind speeds values that were observed more frequently and frequency histogram was used for selection wind turbines. According to Fig. 4 and Table 3, the wind ward directions are North and Northeast, and the directions where the wind is strongest are same regions.

The power performance curve provided by the wind turbine manufacturer is an averaged value measured at the test field. However, the power output from the turbine may not be consistent and probably reveals slightly different power performances day by day. Therefore, the probability approach is required in order to assess the power performance of a wind turbine. The uncertainty of the power performance curve is known to be 6–8%, and that of AEP (Annual Energy Production) is around 8–12% [1,13]. The monthly average wind speeds are illustrated at 10, 20, and 30 m in Fig. 2. The AEP is computed in the case of a 800 kW wind turbine to be installed at Muradiye. Manisa.

The expected energy output per year can be reliably calculated when the wind turbine's capacity factor at a given average wind speed is known. The capacity factor is very sensitive to the average wind speed. When using the capacity factor to calculate the estimated annual energy output, it is extremely important to know the capacity factor at the average wind speed of intended site. Lacking a calculated capacity factor, the machine's power curve can actually provide a crude indication of the annual energy output of any wind turbine. At good wind sites, the annual average production is expected to be between 25% and 33% of the rated capacity. A very good capacity factor would be 40% [10]. As shown in Figs. 2 and 3, the data obtained during the measurements reveal that the capacity factor of the sample turbine (E44) is 12%, and amount of energy that can be produced is 843 MWh for 12 months.

Estimated wind speed is to be 4.34 m/s at 65 m height. At this stage, it is expected that capacity factor can reach 14.1%, and amount of energy that can be produced is 991 MWh/year.

4. Conclusions

In this study, wind energy potential of Celal Bayar University Muradiye Campus has been investigated. The results were given and discussed. The experimental results indicate that the mean wind speed does not provide economical electricity production from the wind energy. Instead of E44 wind turbine may be selected different wind turbine such as Enercon E70 or E82. However, to be selected turbine model and its tower height or more turbine blade length may increase only 1–2% capacity factor, yet the measurements should be extended long term for defining more realistic wind energy potential of the site and suitable wind turbine type and technology selection.

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